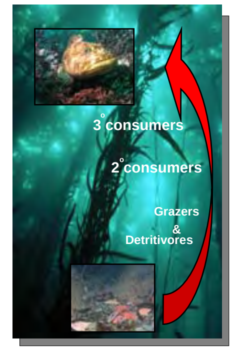
Temporal and Spatial Patterns of Drift Algae

Jared Figurski
University of California, Santa Cruz
Figurski@biology.ucsc.edu

Monterey Bay National Marine Sanctuary

Few ecosystems are as impressive as those that occur within the boundaries of the Monterey Bay National Marine Sanctuary (MBNMS). Primary productivity of kelps and other algae, driven by upwelling of nutrient rich waters, is the foundation for diverse communities of birds, mammals, algae, fish and invertebrates.



Giant kelp, *Macrocystis pyrifera*

Giant kelp, *Macrocystis pyrifera*, is one of the fastest growing organisms (~33cm/day) and forms spectacular underwater forests that provide food and habitat for some of the most productive and diverse ecosystems on earth. *M. pyrifera* grows to lengths of 30 meters resulting in enormous standing biomass and staggering annual production of >9500 metric tons/km coastline.

What happens to productivity?

Kelp forest ecosystems depend on energy and nutrients provided by kelps and other algae. However, most biomass is not directly grazed and instead becomes drift algae that falls to the seafloor and degrades, fueling highly productive detritus-based food webs. Spatial and temporal patterns of drift algae abundance drive processes that structure kelp forest food webs. Consequently, understanding processes like these are becoming increasingly important as climate change threatens to alter global oceanography (e.g. upwelling patterns, storm intensity, and sea surface temperature) that will likely have severe consequences for kelp production.

Survey Methods

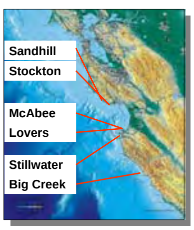


Figure 1: Map of surveyed kelp forests

I monitored the abundance of drift algae using SCUBA surveys for 3 years in 6 kelp forests throughout the MBNMS. Surveys were conducted in June, August, October and January to detect seasonal variation. At each location, 6 transects were run cross-shore from 6 to 18m depth, and a minimum of 15 quadrats (1m^2) were placed uniformly. I recorded percent cover of drift algae, composition, depth, aspect, relief, and substrate. In addition, I surveyed densities of *M. pyrifera* stipes in 12 additional transects at each location. All of these measurements were used in a multiple regression to understand how reef characteristics and kelp production explain variation in drift algae abundance.

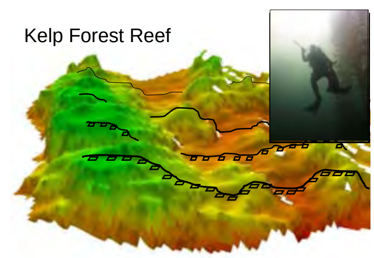


Figure 2: Schematic of survey method. Transects run cross-shore from shallow to deep with uniformly placed quadrats.

Patterns

(1) Standing biomass of drift algae differs substantially between kelp forests by as much as 5 times (figure 3)
  -Kelp forests north on Monterey Bay have far less drift algae than southern kelp forests
(2) Spatial patterns of drift algae biomass are consistent across years (figure 3)
(3) Biomass of drift algae varies seasonally. (figure 4)
  -Highest biomass at 5 of 6 forests was in mid-summer. Highest biomass at big creek was in fall.

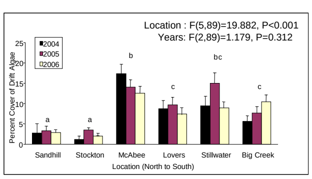


Figure 3: The standing stock of drift kelp measured in 6 kelp forests during the summers (July-August) of 2004, 2005, and 2006. Lower case letters indicate locations that do not differ. The northern forests, located north of Monterey bay, had substantially lower cover of drift kelp (M=3.50, SD=5.37) than all of the sites to the south (M=10.66, SD=5.22).

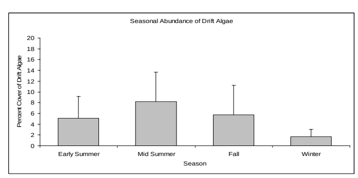
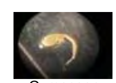


Figure 4: Seasonal patterns of drift algae abundance. Totals are averaged across all 6 kelp forests.



Cumacean

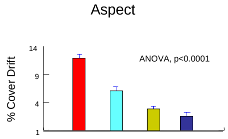
Gammarid

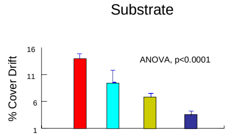
Leptostracans

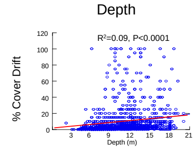
What Drives the Patterns?

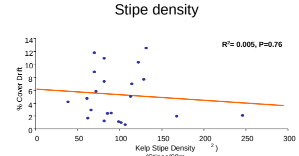
Standing biomass of drift algae is a balance between its production and loss. While production is clearly important and likely explains seasonal trends of abundance, wave energy is capable of exporting large volumes of drift algae, thereby decoupling local production from drift algae abundance. Consequently, reef morphologies that reduce rates of export are very important, accounting for 90% of the explained variation in the multiple regression:

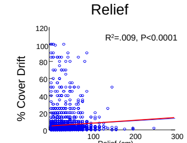
Drift Biomass=	Aspect +	Substrate +	Depth +	Stipe Density +	Relief	reef morphology
Contribution	(34.1%)	(30.8%)	(20.4%)	(9.7%)	(5.0%)	production











Implications

Drift algae is one of the main sources of nutrients and energy in kelp forests. Understanding dynamics of drift algae and, in turn community response, underpins ecosystem-based management. The results of this study demonstrate that although productivity can be highly variable, food abundance for detritivores may actually be constrained by reef morphology. This has exciting implications for predicting resource availability to basal levels of kelp forest food webs.

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